Retinex Image Enhancement: Application to Medical Images

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# Retinex Image Enhancement – General Information

- The Multiscale Retinex with Color Restoration – Retinex for short – is a general-purpose image enhancement algorithm.

- It is patented:
    - US patent #5,991,456, and two others pending
    - Australia patent #713706 (International #US97/07996)
    - Pending in several other Asian and European countries

- TruView Imaging Company, Hampton, Virginia, holds the exclusive licensing rights.

Retinex Image Enhancement – Potential Applications

• Any medical imaging application where automatic contrast enhancement and sharpening is needed. Potential areas of impact may include:

– Digital X-ray
– Digital mammography
– CT scans
– MRI

• Telemedicine applications where bandwidth between doctor and patient poses a potential bottleneck. The Retinex compacts the high input dynamic range, potentially reducing the high bandwidth requirement.
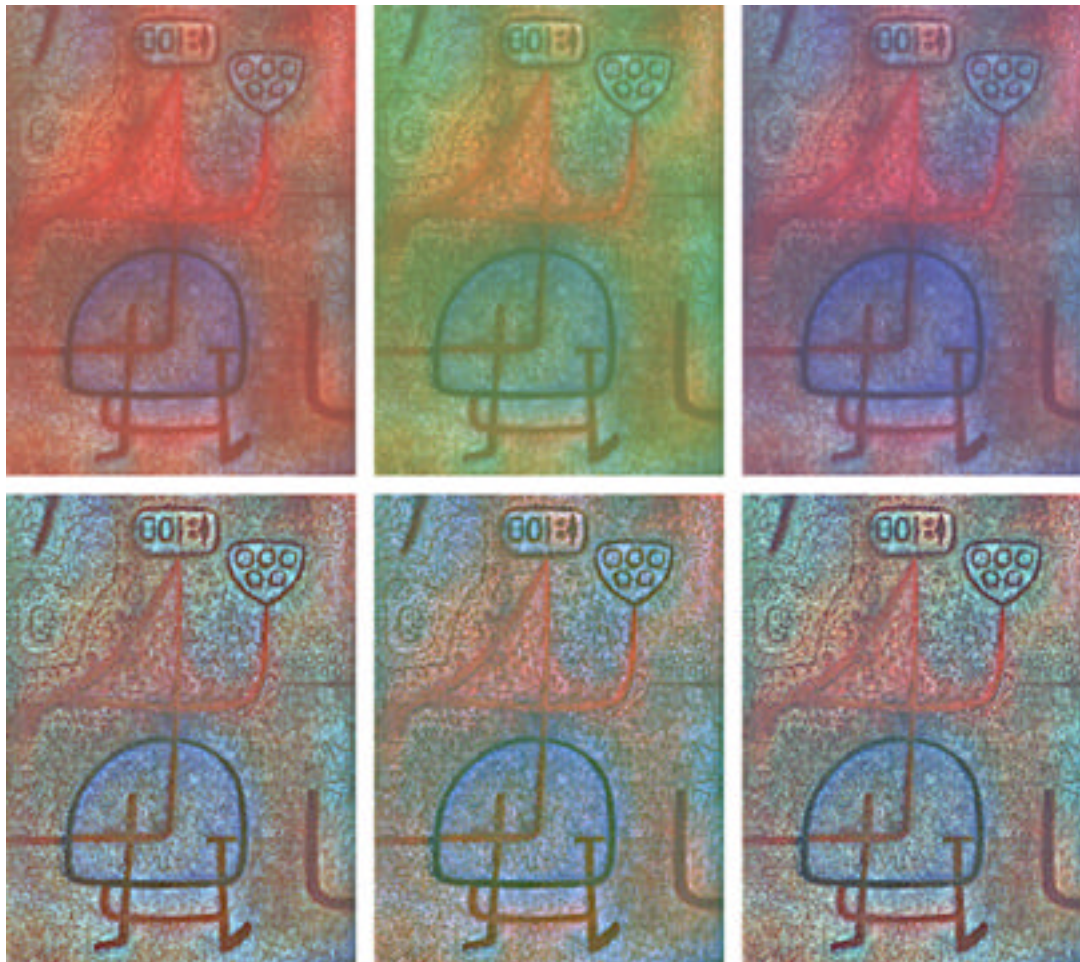
Retinex Image Enhancement – Background

- The Retinex provides automatic

– Dynamic range compression: i.e., the ability to represent large input dynamic range into relatively small output dynamic range.
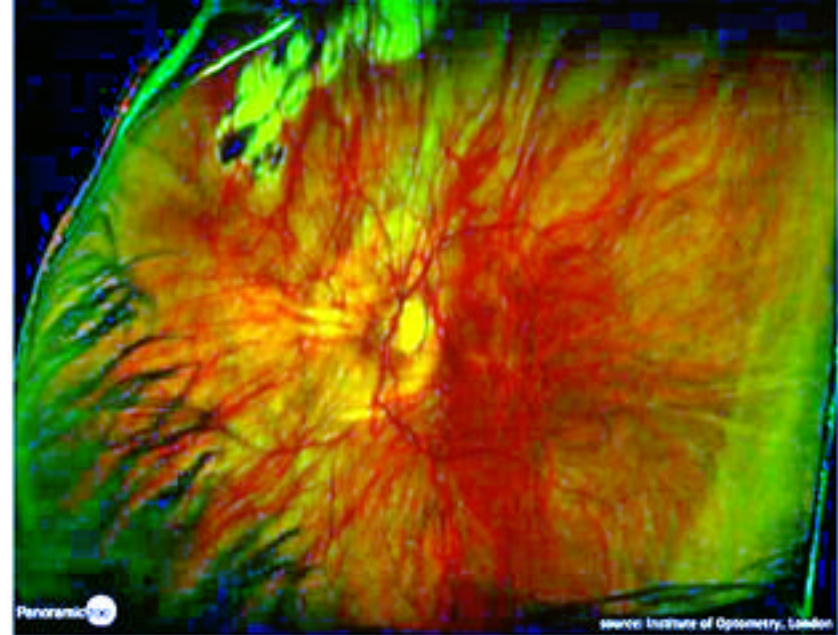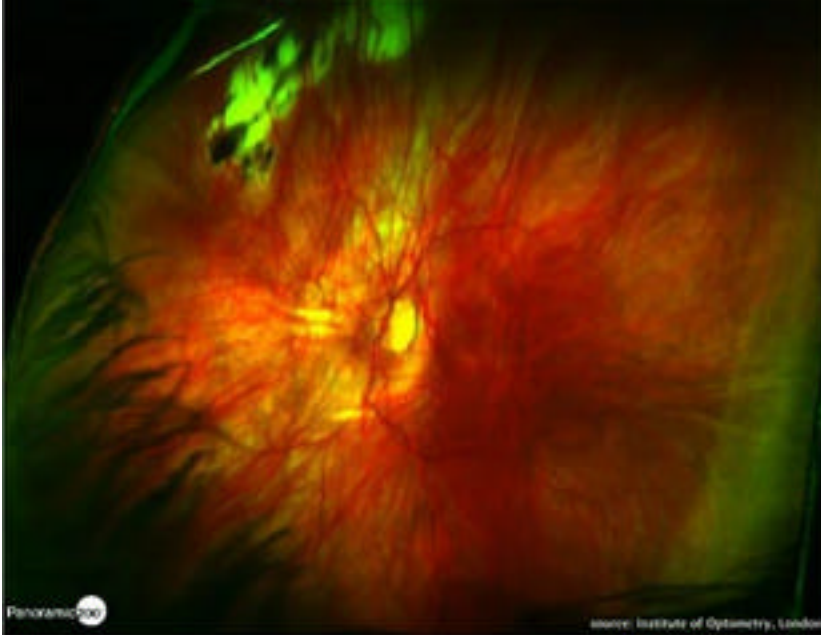
– Sharpening: i.e., compensation for the blurring introduced into the image by the image formation process. This allows fine details to be seen more easily than before.

– Color constancy: i.e., the ability to remove the effects of the illumination from the subject. This allows consistency of output as illumination changes.

Retinex Image Enhancement – Technical

• The Retinex takes an input digital image I and produces an output image R on a pixel by pixel basis in the following manner:

$$
\begin{aligned}
R(x, y) &= \log\left(I(x, y)\right) - \log\left(I(x, y) * M(x, y)\right) \\
&= \log\left(\frac{I(x, y)}{I(x, y) * M(x, y)}\right)
\end{aligned}
$$

where $M(x, y) = \exp\left((x^2 + y^2)/\sigma^2\right)$, σ

is a constant which controls the extent of M, and * represents spatial convolution

• This non-linear transform has some interesting properties:

– It mimics the spatial aspect of color perception by setting the output value as a function of the center (numerator in the equation) and its surround (denominator in the equation).

– The ratioing operation in conjunction with the log function inherently performs dynamic range compression.

– The output is independent of the illumination source.

- The input image can be written as the product of two components:

$$\rho(x,y)$$

the reflectance component which represents the light reflected from all the objects in the scene being imaged, and $i(x,y)$ which represents the illumination component: That is,

$$I(x, y) = i(x, y)\rho(x, y).$$

- Since the illumination component varies very slowly across the scene, $I(x, y) \approx I_o\rho(x, y)$, and

$$
\begin{aligned}
R(x, y) &= \log\left(\frac{I_o\rho(x, y)}{I_o\rho(x, y) * M(x, y)}\right) \\
&= \log\left(\frac{\rho(x, y)}{\rho(x, y) * M(x, y)}\right)
\end{aligned}
$$

- By performing the same operation on each color channel, the output color image can be written as

$$R_i(x, y) = \log \left(\frac{I_i(x, y)}{I_i(x, y) * M(x, y)} \right) \quad i \in \{R, G, B\}$$

- $R_i(x, y)$ Is dependent upon the size of the surround mask $M(x, y)$ which is paramterized by σ.

- Different values of σ enhance different features of the input image: large values provide good spectral information, and small values provide good spectral information.
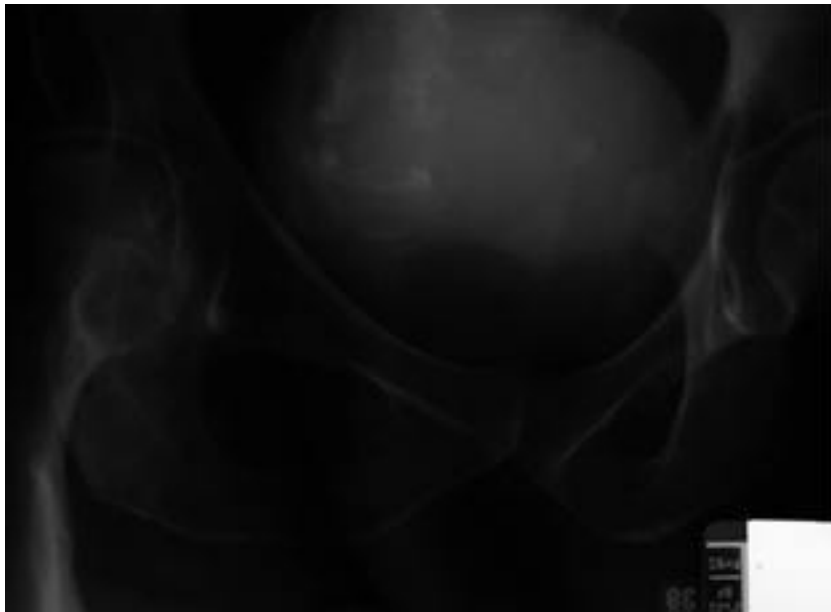
- So,

$$R_i(x, y) = \frac{1}{K} \sum_{k=0}^{K} \log \left(\frac{I_i(x, y)}{I_i(x, y) * M_k(x, y)} \right), i \in \{R, G, B\}$$

Retinex – Examples

• Many digital medical images suffer from lack of contrast and sharpness.

• The Retinex automatically provides both enhanced contrast and sharpness.

• The following slides show the application of the Retinex image enhancement algorithm to

– X-rays
– Mammograms
– CT scans
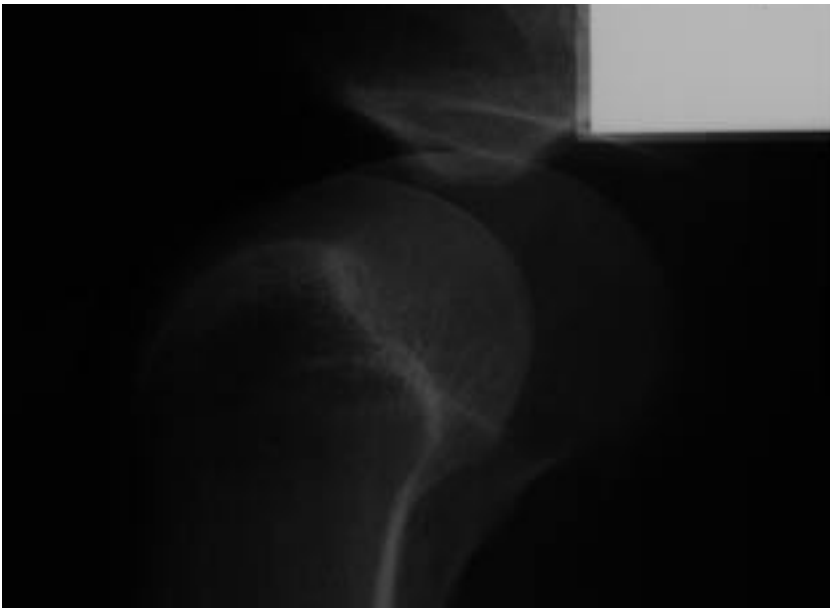– Other medical images

Retinex – Examples – X-rays

Original

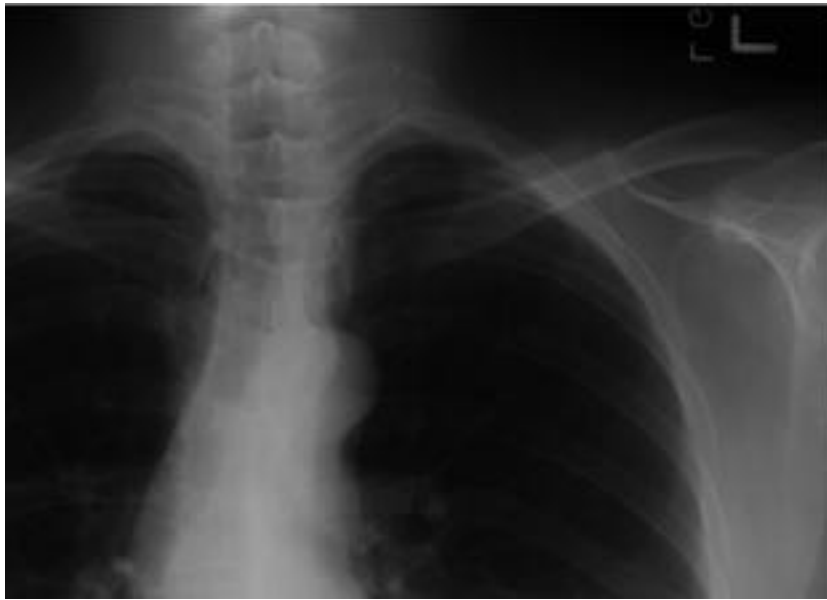
Retinex

Retinex – Examples – X-rays
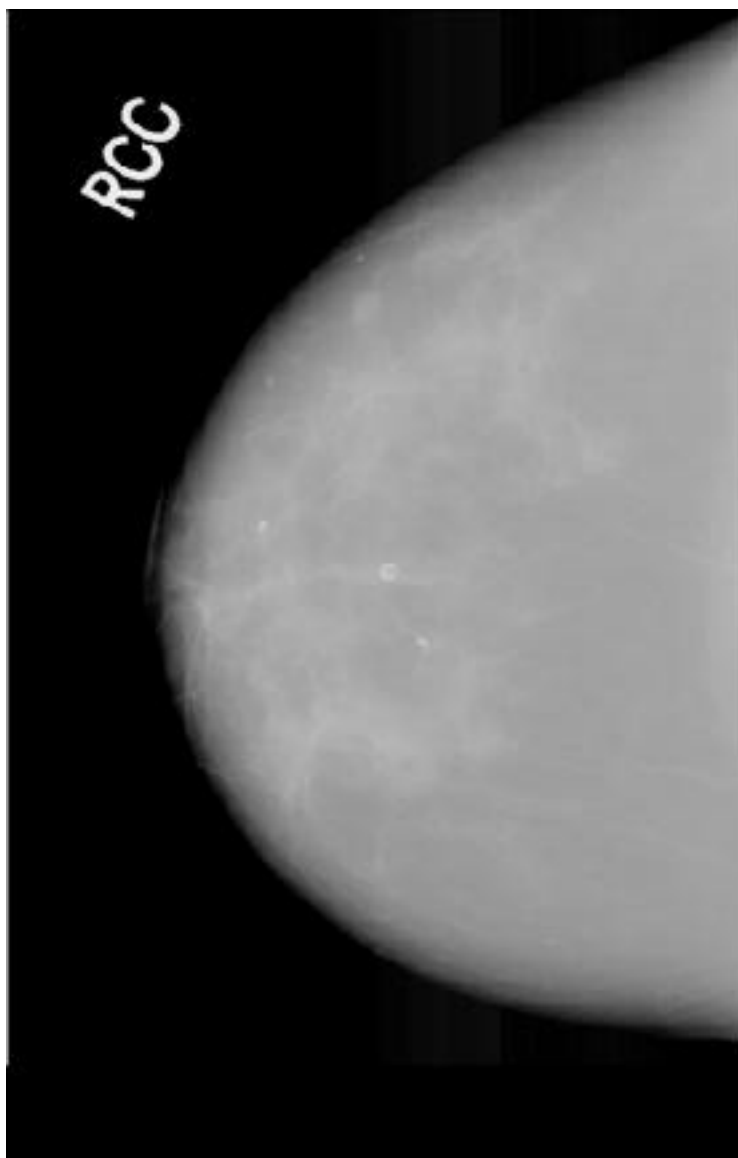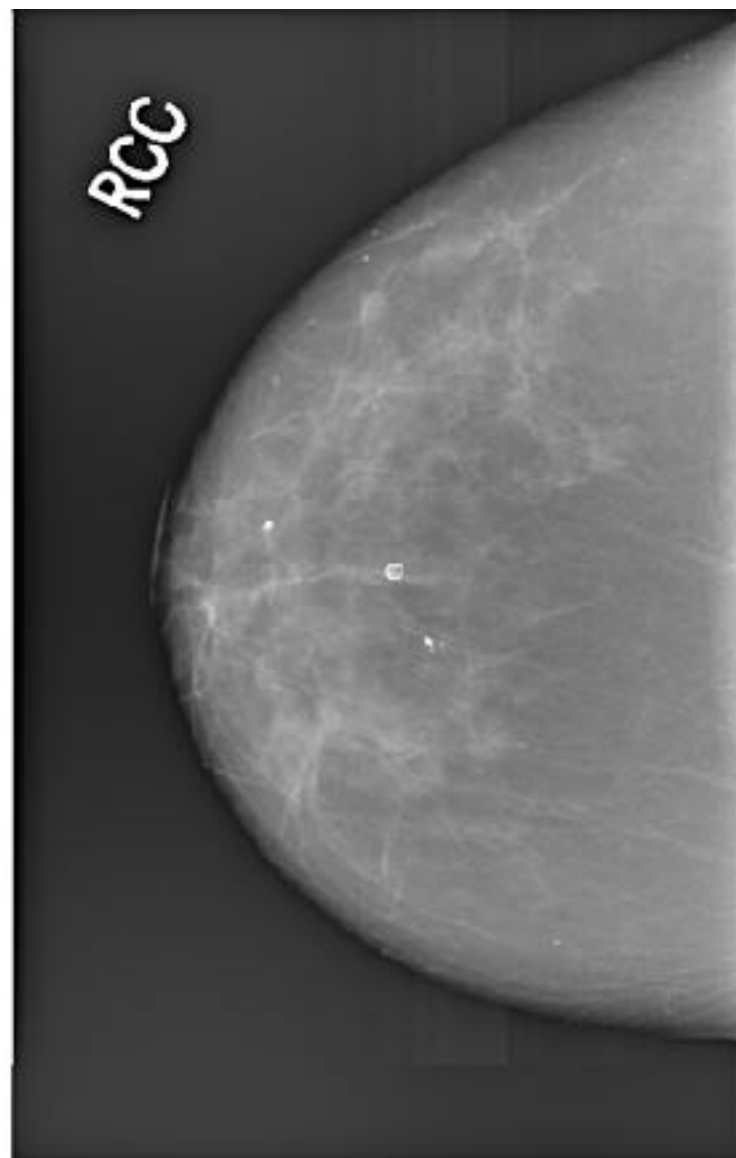

Original

Retinex

Retinex – Examples – X-rays

Original

Retinex

Retinex – Examples – Mammograms
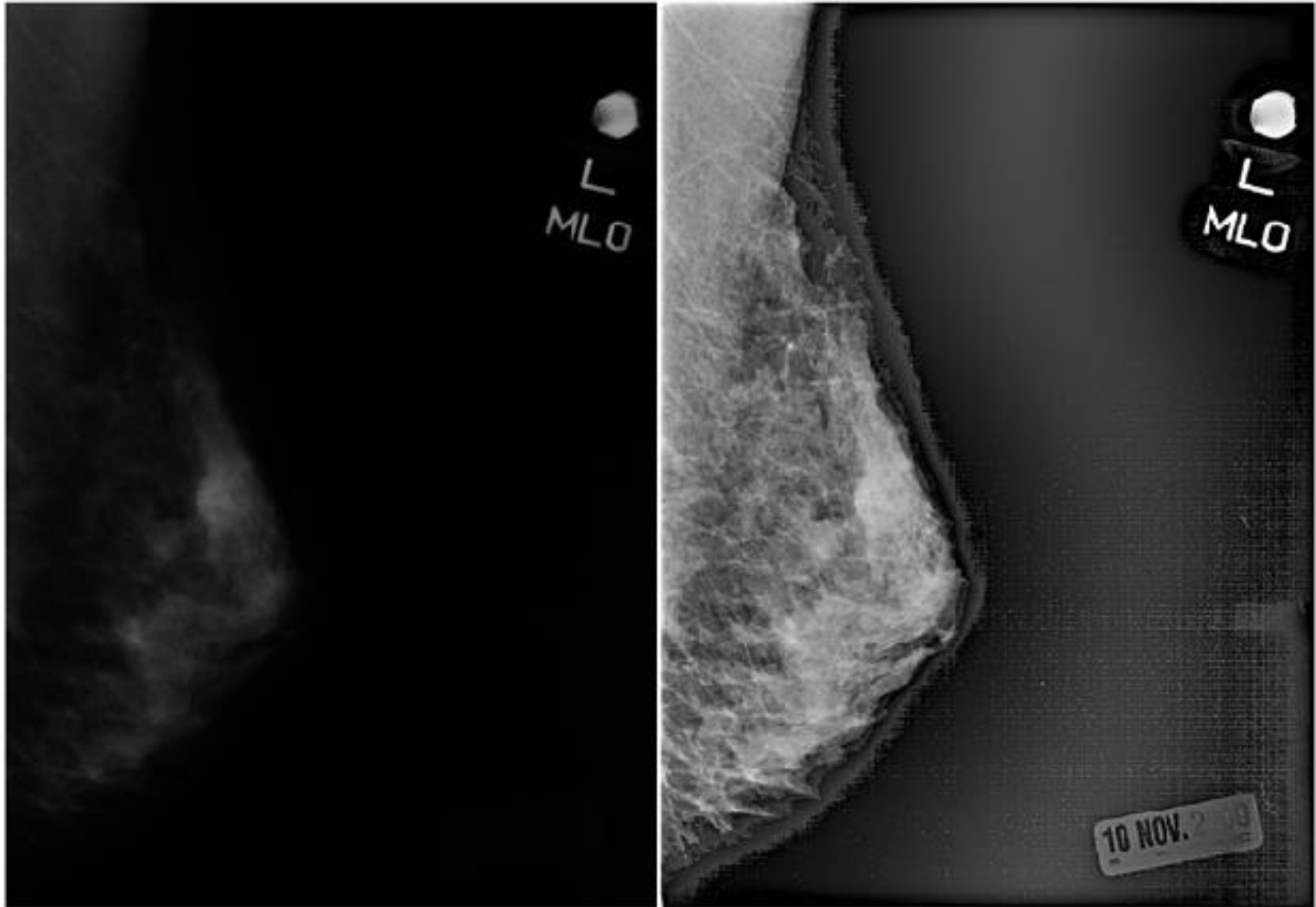

Original

Retinex

Retinex – Examples – Mammograms

Original

Retinex
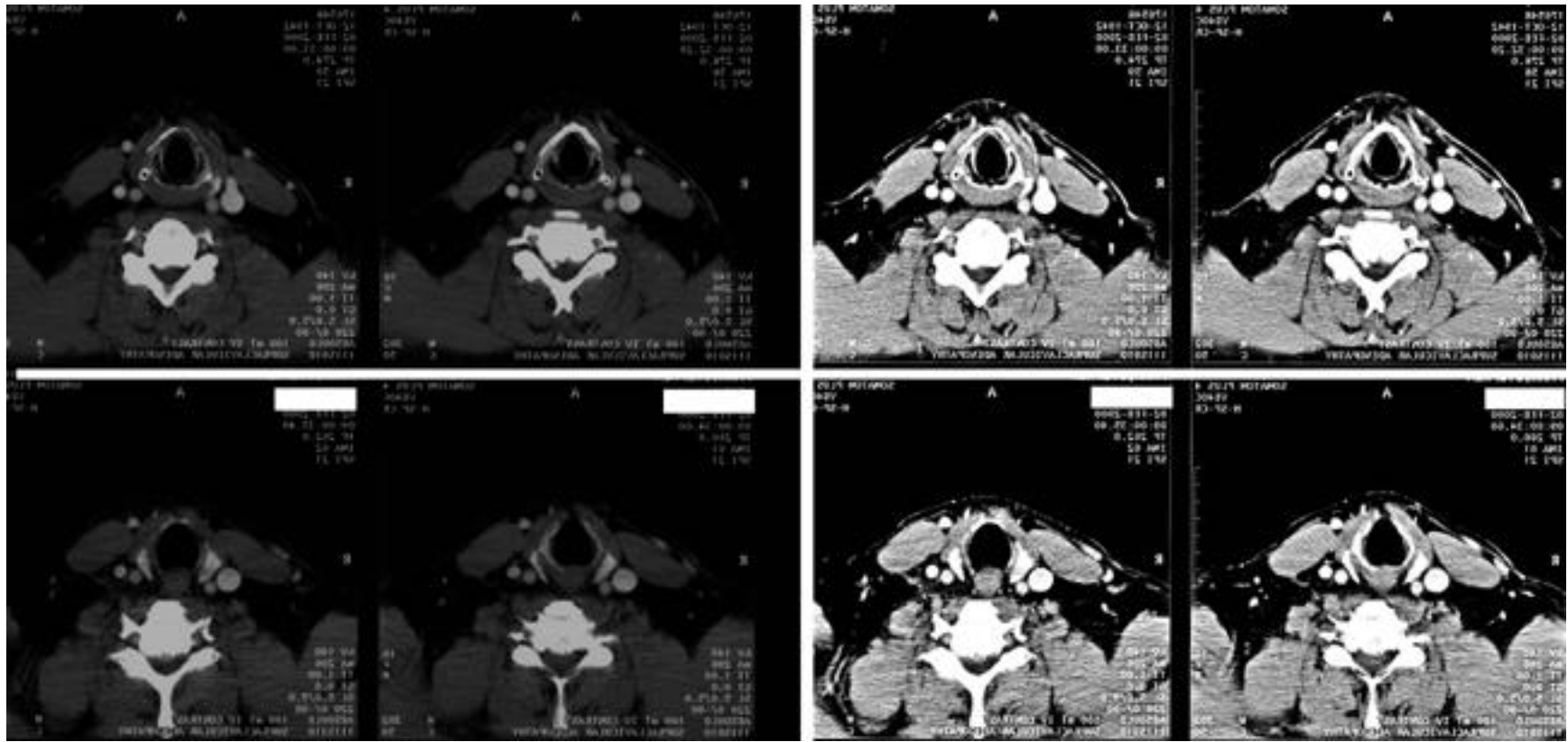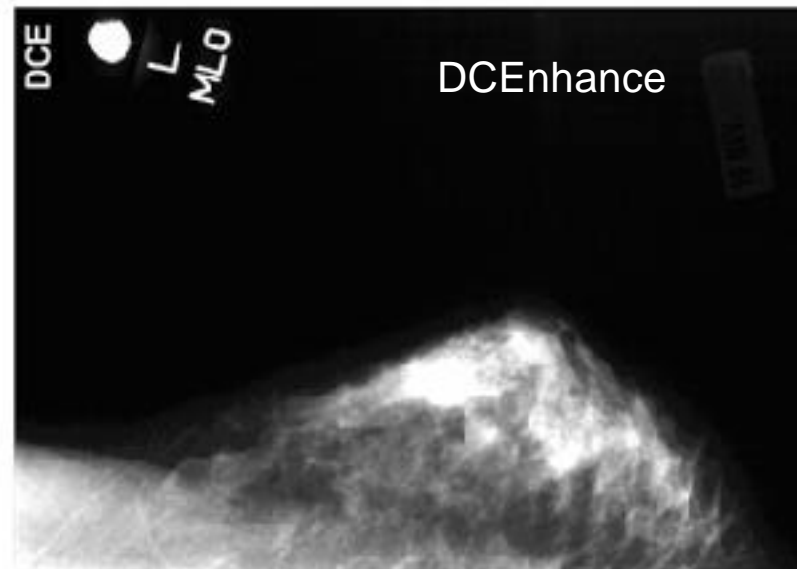
Retinex – Examples – CT Scans
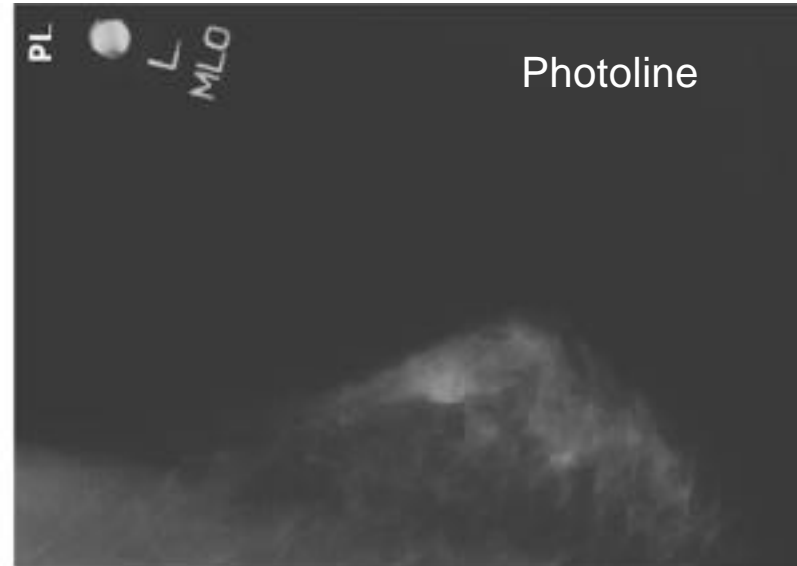

Original

Retinex

Retinex – Examples – CT Scans

Original   Retinex

Retinex – Examples – Comparisons
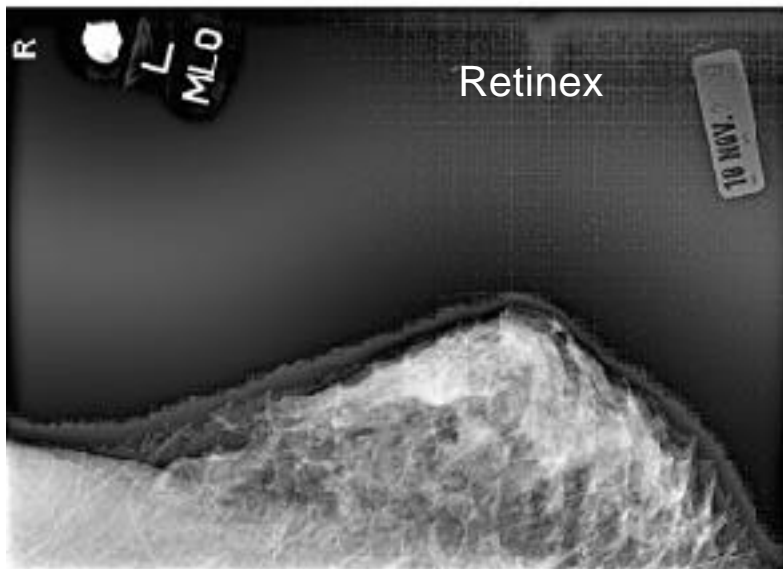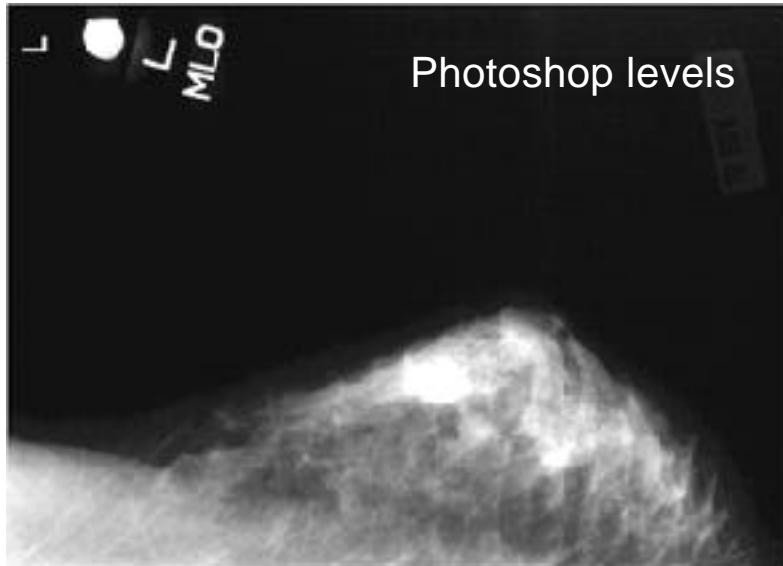
Photoshop levels

Photoline

Retinex

DCEnhance

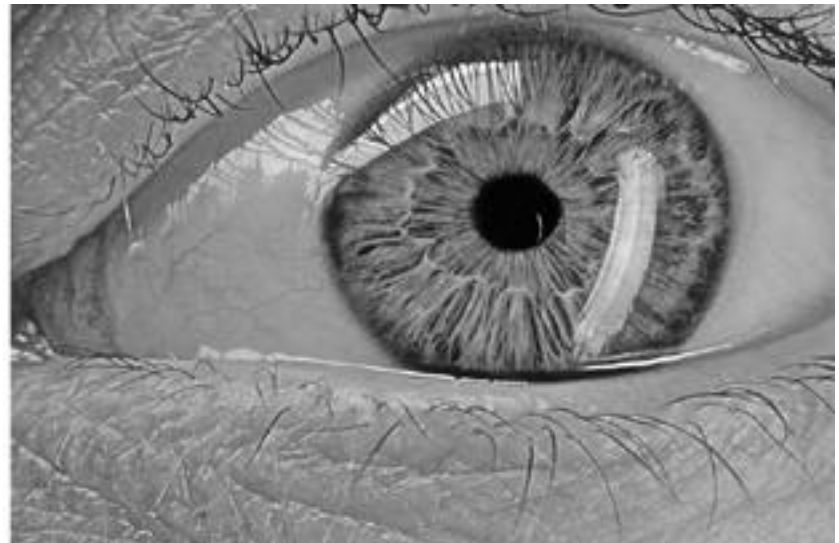# Retinex – Examples – Other

Original

Retinex

Retinex – Examples – Other

Original

Retinex

Retinex – Examples – Other

Original

Retinex

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